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ASD-TR-68-8

Project Muddy Hill
(Unclassified Title)

William M. Kovalick, Lt Col., USAF

Michael J. Trimpert, Capt., USAF

AD 389302

TECHNICAL REPORT ASD-TR-68-8

March 1968

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Deputy for Limited War
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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FOREWORD

This project was conducted by the U.S. Navy as a Department of Defense approved R&D effort. Air Force participation included assignment of two Air Force liaison officers and normal base support during overseas deployment. No Air Force funding was involved. Periodic activity reports were distributed to appropriate Air Force organizations with interest in this type of activity. Some additional testing of subsystems is continuing at Patuxent NAS, Maryland, but Project MUDDY HILL is essentially completed and its resources absorbed into the U.S. Navy TRIM program.

This technical report has been reviewed and is approved.

ABNER B. MARTIN
Chief, Technical Operations Division
Deputy for Limited War

ABSTRACT

Project Muddy Hill was established to evaluate the feasibility of an airborne multi-sensor night reconnaissance system. It was a Navy project, with a modified Lockheed P-2H as the test vehicle and U.S. Navy personnel from Patuxent NAS, Maryland, assigned to manage and carry out the test program. Two Air Force officers participated in the program as an Air Force liaison team.

The primary sensors contained in the aircraft were a real-time forward looking infrared scanner, a low light level television, and a pair of downward looking infrared recording devices. After equipment installation, some testing was accomplished at Greenville, Texas, and Patuxent River, Maryland, before the project deployed to Southeast Asia for operational testing and evaluation.

The project was located at Udorn RTAFB, Thailand, for four months, and operational missions were flown over enemy occupied areas of Laos. Numerous technical problems associated with the equipment resulted in excessive out-of-commission status and marginal operational capability. It must be concluded that the project was unsuccessful in performing effective reconnaissance in mountainous jungle terrain but its primary value was in revealing deficiencies to be corrected in follow-on programs.

In addition to security requirements which must be met, this abstract is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Technical Operations Division, Deputy for Limited War, Wright-Patterson Air Force Base, Ohio 45433.

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SECTION I

INTRODUCTION

The enemy tactics and the topography associated with the conflict in Southeast Asia created a unique problem which established a need for a more effective and possibly new type of night reconnaissance capability. In an effort to meet this challenge, Project MUDDY HILL was conceived and proposed to the Department of Defense on 23 July 1965. Conceptually, the project was designed to provide a self-contained capability to:

a. Fly to a pre-selected point.

b. Search for and locate targets.

c. Collect the essential intelligence.

d. Mark targets for follow-up action.

e. Furnish "hard copy" data for post-mission analysis.

The concept was approved and efforts immediately undertaken to translate the proposal into a working system. A Navy P-2H was made available as the test vehicle, and the US Naval Air Test Center at Patuxent River, Maryland, assumed operational control over the project. LTV Electrosystems, Inc., Greenville, Texas, was selected as the prime contractor to modify the aircraft and install and integrate the various subsystems. Contract go-ahead was given on 8 February 1966, and the P-2H was delivered to Greenville, Texas, in March 1966. Figure 1 shows the aircraft configuration.

LTV proceeded with the modifications and meanwhile, in August 1966, the Navy aircrew and maintenance crew arrived at Greenville. The Navy force consisted of seven officers and 16 enlisted men. The plan at that time called for flight testing and equipment shake down until 1 December 1966, at which time the project was scheduled to deploy to Thailand for operational testing. Since most of the equipment was highly developmental, numerous problems were encountered which caused successive slippages in the deployment schedule.

In December 1966, an Air Force staff office (AFRDDH) requested two Air Force officers be assigned to participate in the project and secure information which might be useful in the Air Force Shedlight program. Consequently, one officer from AF Systems Command and one from TAC were assigned TDY to accompany the project to Southeast Asia. Also, the Navy maintenance crew was augmented with five contractor technical representatives for the overseas deployment.

The project deployed during July 1967 to Udorn RTAFB, Thailand, and conducted test and operational flights from that location until the end of November 1967. Operational flights were flown over northern Laos and over Route 110 in southern Laos (sometimes referred to as "The Sihanouk Trail") to gather both real time and hard copy intelligence. The aircraft contained no strike capability.

The original deployment schedule called for three months at Udorn to conduct reconnaissance over Laos and three months at Tan Son Nhut to reconnoiter the MeKong Delta and coastal areas of South Vietnam. However, because of continuing problems with the sensor equipment, the Chief of Naval Operations, Washington, D.C., directed the project to extend at Udorn for an additional month and delete the Vietnam phase. The project terminated on 1 December 1967 and returned to the United States.

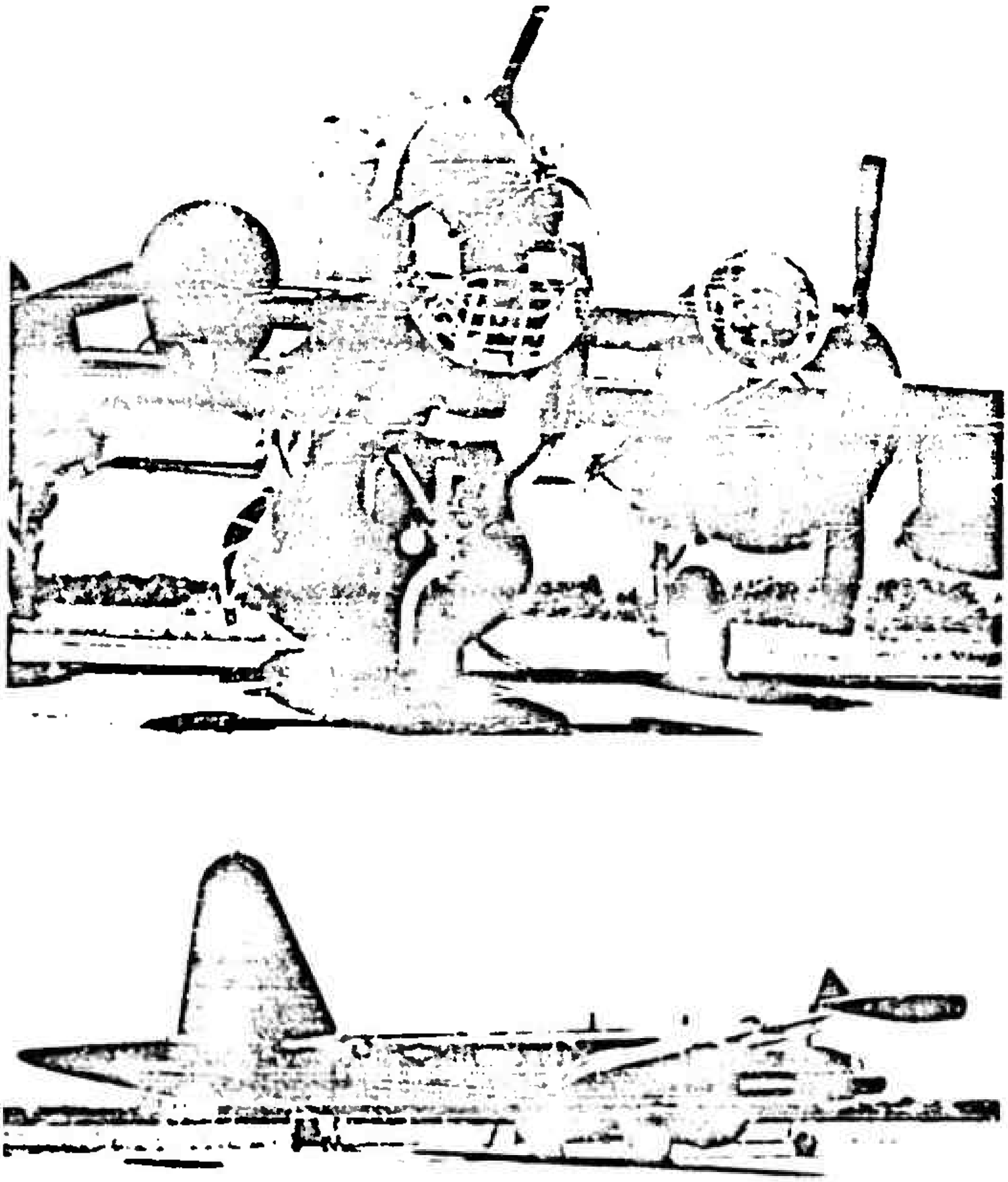


Figure 1. P-2H Configuration

SECTION II

DESCRIPTION OF EQUIPMENTS

A list of equipments installed on the aircraft is given below. Figure 2 shows the equipment layout. Figure 3 gives the sensor coverage obtained from an altitude of 1000 feet. A description of the major equipments is included in Appendix I.

1. LIST OF EQUIPMENTS

a. Sensors

(1) Downward Looking Infrared System (DLIR) - Two D-5's - Texas Instruments, Inc.

(2) Forward Looking Infrared System (FLIR) - FLIR III - Texas Instruments, Inc.

(3) Low Light Level Television (LLLTV) - Dalmo-Victor, Inc.

(4) Active Magnetic Detection System (AMDS) - Electro-Mechanics Co.

(5) Starlight Scope - Electro-Optics Systems, Inc.

b. Navigation Equipment

(1) LORAN C - AN/ARN-78 (modified) - Sperry Rand Corp.

(2) Inertial Navigation System - LN-15 - Litton, Inc.

(3) Versatile Digital Analyzer (Verdan) Computer - Autonetics Div., North American Rockwell Corp.

(4) Doppler Radar Set - AN/APN-153(V) - General Precision, Inc.

(5) Navigation Track Computer - AN/ASN-25 - General Precision, Inc.

(6) Roller Map Dead Reckoning Display - AN/ASN-67 - Applied Sciences, Inc.

c. Miscellaneous

(1) Terrain Following Radar (TFR) - APQ-110 - Texas Instruments, Inc.

(2) Digital Data System

(3) Mark II Panoramic Camera System - Perkin-Elmer, Inc.

(4) KA-53A Camera System - Chicago Aerial Industries, Inc.

(5) Aerograph Set - AN/AMQ-17

(6) Radar Altimeter

(7) TRIM 7 and Vector Sector ECM

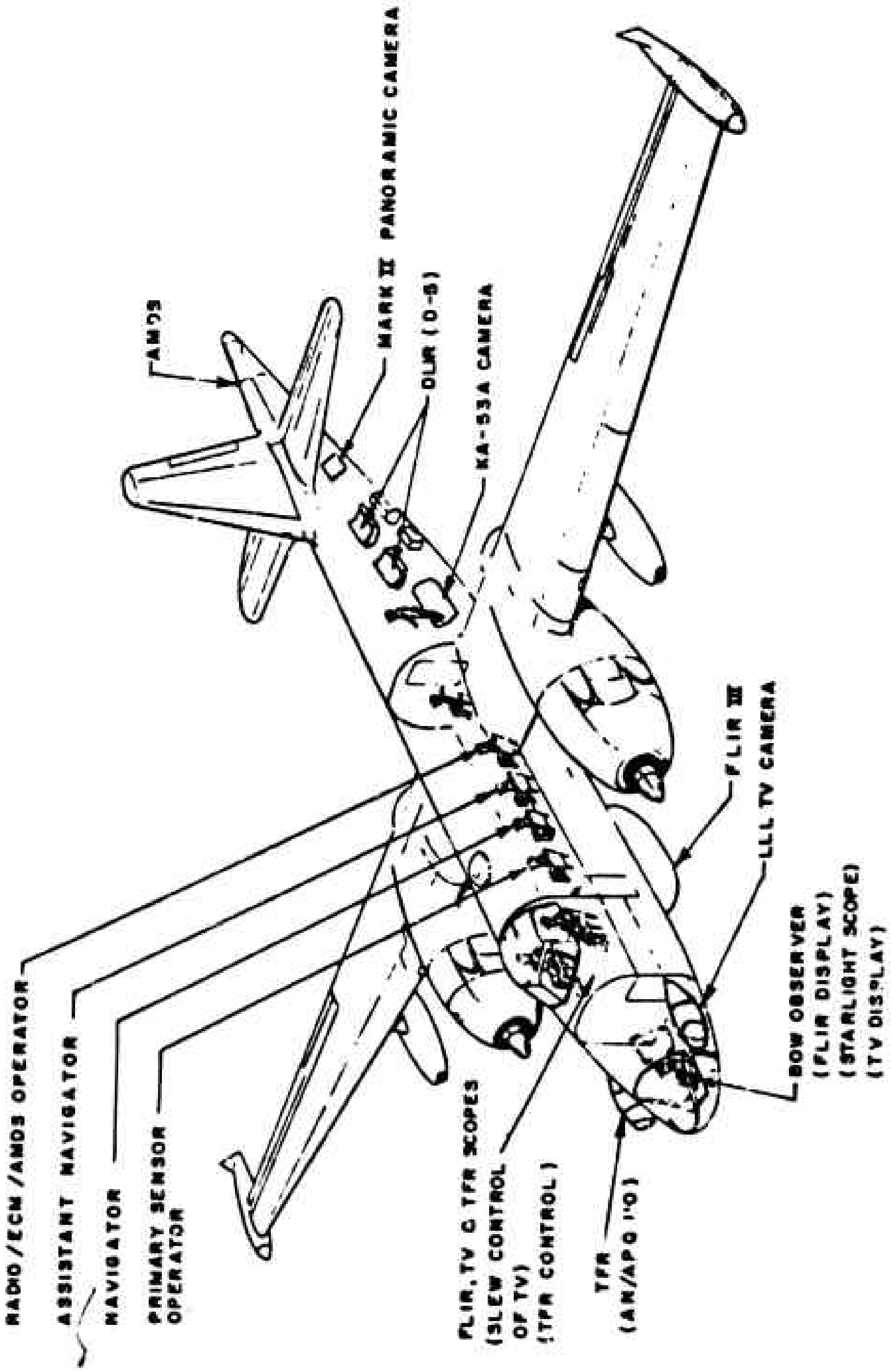


Figure 2. Equipment Layout

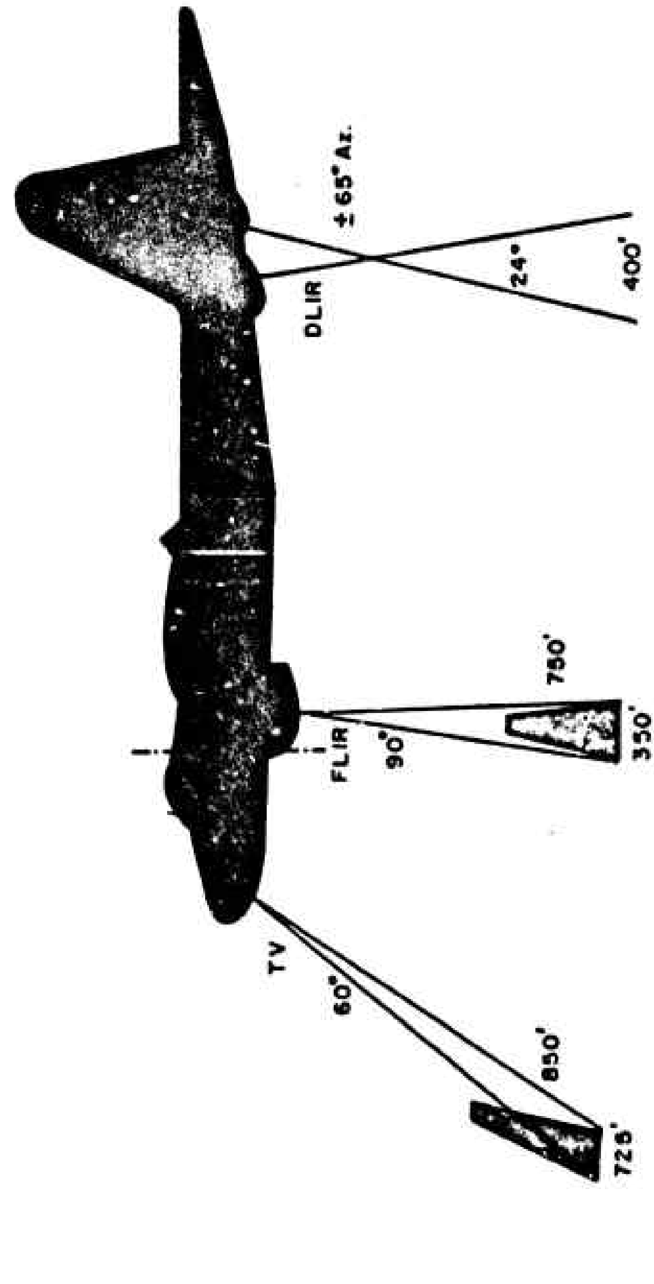


Figure 3. Sensor Coverage at 1000 Feet

SECTION III

SUMMARY OF FLIGHT OPERATIONS

Testing in the Southeast Asia environment was conducted from 2 August 1967 to 26 November 1967. The flight program consisted of the following categories:

a. Road and river reconnaissance missions on Route 110 and the XeCong River in Tiger Hound section of Laos; 11 sorties - 49.3 hours.

b. Infrared mapping missions in the Barrel Roll sector of Laos; 3 sorties - 9.5 hours.

c. Testing, training, and equipment check-out flights in the local area; 48 sorties - 97.1 hours.

All the flights in category a. above, with one exception, were night missions, deliberately flown at various hours of darkness in order to cover a wide range of thermal contrasts among ground objects. The one exception was a high altitude (3,000 feet) day familiarization flight. Two of the flights in category b. were flown at dawn, and the third was flown just after dusk. These times were selected to coincide with enemy housekeeping activities. The local flights of category c. were flown during random day or night hours, depending upon the purpose of the mission. Figure 4 shows the location of the operational flights.

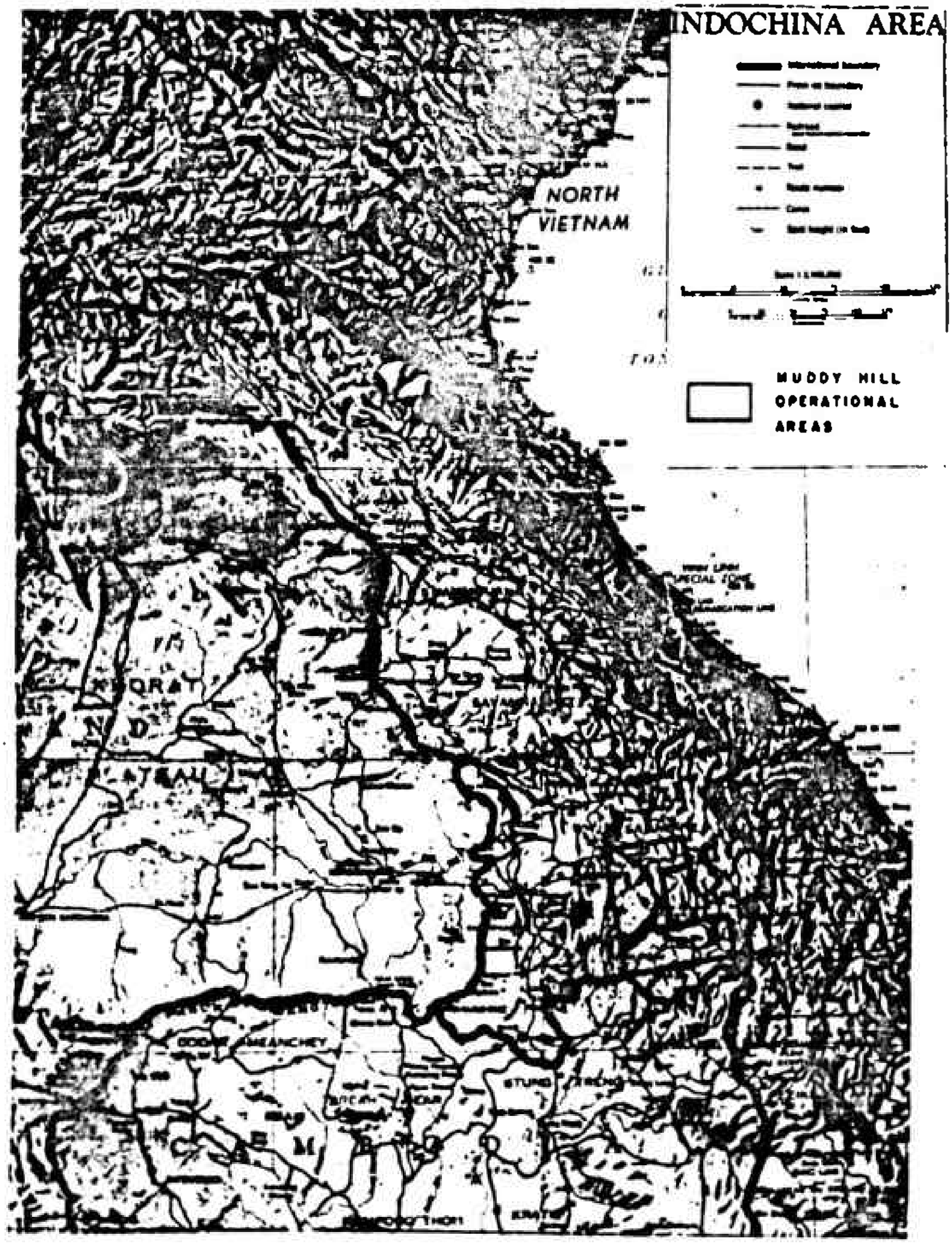


Figure 4. Map of Operational Areas

SECTION IV

OPERATIONAL RESULTS

1. FORWARD LOOKING INFRARED SYSTEM (FLIR)

The FLIR III was tested under daylight and nighttime conditions, during rainy and dry seasons, and at altitudes from 500 to 5,000 feet. In general, vehicle detection was achieved on hard surfaced, two lane highways. However, the FLIR was unsatisfactory as a vehicle detector at night on narrow, dirt, motorable trails. A certain degree of vehicle detection capability was demonstrated in the Udorn local area, but only on clearly defined, two-lane, hard surface, and improved dirt roads. Detection was even difficult on these local roads, since moving vehicles appeared as cold targets and had little contrast relative to trees and vegetation. Classification was primarily made by target shape and relative motion. The FLIR was operational on six of the road/river reconnaissance missions in Southern Laos. During these flights, the FLIR did not acquire any targets which were not easily revealed to the bow observer with a starlight scope. Furthermore, it could not detect watercraft on the XeCong River which were later perceived on the DLIR imagery. It was able to detect fires, bomb craters and, in a few cases, huts and buildings. An attempt was made to use the FLIR as a navigation aid in attempting to follow a road or a river. Occasionally the sensor operator could pick up the road or river and relay steering commands to the pilot; although the FLIR was not able to demonstrate this capability consistently.

It is felt that a number of factors contributed to the inability of FLIR III to detect vehicles. These factors were:

a. Degradation of the presentation at the display caused by electronic noise (S/N ratio).

b. Display size (3" x 6") was considered too small for target detection and classification.

c. Low grazing angle caused by the low altitude of operation (1,000 ft) which is required for sensor detection capabilities. As a result, the masking by the trees will inhibit target detection. In fact, to the FLIR operator, trees overhanging a road look like vehicles.

d. Lack of thermal contrast between trucks and vegetation. Single lane roads are the same width as the trucks, so the cold trucks blend with the cold foliage, making target definition by shape practically impossible.

e. Weather conditions during the rainy season. Rain, little heating by the sun, etc. could have contributed to the poor performance during the months of Sept and Oct.

Further items of note which in themselves did not directly affect target detection capability, but which must be considered in an evaluation of FLIR III were:

a. The detection range of the FLIR is very limited. The earliest the operator could pick up vehicles (on well defined, two-lane roads) was at 60 degrees depression angle, which corresponds to about 1200 feet slant range or about 600 feet ground range. In most cases, the operator had to slew the scanner to nadir to follow the target for definite classification.

b. The FLIR III is not roll stabilized, which results in loss of desired viewing area during aircraft movements. This, coupled with the FLIR's narrow field of view, restricts its usefulness while the aircraft is maneuvering.

c. The altitude capability of the FLIR is limited. The minimal detection capability restricted its use to altitudes between 1,000 and 2,000 feet. In enemy defended mountainous terrain, these are not desirable operating altitudes. Raising the altitude would not only improve this situation, but would also aid in eliminating the masking problem referred to previously.

d. A FLIR monitor was originally installed in the cockpit, but was considered to be of no useful value to the pilot for either target detection or navigation. The FLIR's short range, lack of roll stabilization, and the fact that it can only be controlled by the sensor operator makes it unsatisfactory for use in the cockpit. In addition, the monitor hinders night vision and could tend to distract the pilot from other instruments.

e. The FLIR experienced numerous maintainability problems, especially with detectors and coolers during the testing period. It was operational mainly during the period of 24 August 1967 to 13 October 1967, after which the cooler failed completely. A new cooler assembly arrived on 2 November 1967, and a Texas Instruments FLIR expert arrived on 17 November 1967 in a final effort to improve the performance of FLIR III. After several days of maintenance and adjustments, the FLIR produced a highly satisfactory monitor presentation in the laboratory. It was installed in the aircraft on 22 November and was operated for a total of four flights before the completion of flight operations. The improved presentation produced in the laboratory was not attained after installation in the aircraft, and no significant improvement in target detection capability was noted during these final four flights.

2. DOWNWARD LOOKING INFRARED SYSTEM (DLIR)

The DLIR, like the FLIR, was tested during all hours of the day and night in both rainy and dry weather conditions. Normal altitude for DLIR operations was 1,000 feet. For the first 1 1/2 months of the deployment, only the aft D-5 system was in operating condition. The cooler for the forward system was damaged in transit from Texas Instruments and, due to various delays, was not operational until 20 September 1967.

The two D-5's produced imagery rated from poor to very good by a Photo Interpreter (PI) from the "Compass Eagle" program at Tan Son Nhut. The "Compass Eagle" program is an evaluation of the RS-10 Downward Looking Infrared Systems made by Texas Instruments and installed in three RB-57a. The PI analyzed imagery taken from both D-5s for operational as well as test flights during the period 20 September to 20 November and rated the results as follows:

Operational:	Very good	- 15%
(10 flights)	Good	- 20%
	Fair	- 25%
	Poor	- 35%
	No Film	- 5%
Test:	Very good	- 14%
(21 flights)	Good	- 36%
	Fair	- 19%
	Poor	- 24%
	No Film	- 7%

Factors considered in the PI's evaluation were contrast, density and resolution of the imagery obtained, as well as malfunctions which caused unsatisfactory imagery. During his analysis, the PI noted the following problems:

a. Lack of proper focus on the forward system for a majority of the deployment which prevented fine edge definition necessary to identify trucks.

b. Electromagnetic interference or noise causing striations, banding, intermittent video loss, and spikes on the imagery. This interference was caused by aircraft equipment such as the doppler radar set and the TACAN, 400 cycle line noise and externally from the radar equipment of air traffic control centers.

c. The inability of the technicians to properly adjust the systems for contrast, gain, time constant, and cosine settings for optimum imagery.

d. Lack of roll stabilization.

All of the previous problems intermittently and in varying degrees prevented the D-5s from obtaining consistently good imagery. It is evident that these problems were responsible for the failure of the DLIR to provide a positive capability of detecting vehicles on film obtained from operational missions.

Numerous passes were made over a resolution target during the last two weeks of the flight program in an attempt to determine the D-5 spatial resolution capability. It was calculated that the forward D-5 yielded a resolution of about 1.35 milliradians and the aft about 0.69 milliradians. There was reason to believe that the degradation in resolution from the 0.5 milliradian design specification could be attributed to a combination of system electronics difficulties and possible misalignment of internal scanner optics. However, the D-5s can still be considered high resolution systems. Figure 5 is a night photograph of Udorn RTAFB obtained from the forward D-5 system.

In spite of having a high spatial resolution capability and a half degree NET resolution, the D-5s could not, with any degree of consistency, detect trucks on the narrow, dirt, infiltration routes typical of southern Laos. On the last three operational missions along Route 110, a total of 40 trucks was visually sighted. During post flight analysis of the imagery of these missions, photo interpreters were not able to positively identify any trucks on their initial study of the film. After correlating time of the visual sightings with the same time annotated on the film, they were able to identify positively approximately 25% of the trucks. The trucks on Route 110 showed as point source hot targets. The road also showed hot and was narrow enough that the trucks were about as wide as the road. This factor, plus the lack of definition of the trucks, added to the detection problem. The D-5s also had no foliage penetration capability.

The D-5s were readily able to detect boats, both motorized and non-motorized, on the XeCong River in the vicinity of Route 110. Also, water buffalo in open, isothermal fields, wheel ruts in open sections of road, and trees were easily detectable on most imagery. The D-5s also have the capability of producing reasonably good imagery for ground mapping purposes. On well-defined two-lane roads, both paved and unpaved, vehicle targets are easily discernible on D-5 film. Figure 6 contains two samples of IR photography showing vehicles and other objects with fair resolution.

3. LOW LIGHT LEVEL TELEVISION SYSTEM (LLLTV)

The LLLTV was not in working condition for the majority of the deployment, so it was not fully evaluated in the operational environment. It was used for only one operational mission along Route 110 before it was removed for rework. The original SEC-Vidicon tube developed a defect which had become apparent during the flight testing phase at LTV Electrosystems as early as November 1966. About 30% of the area on the monitors became blurred on the center right half of the tube around a halo-like bright spot the size of a quarter. The defect

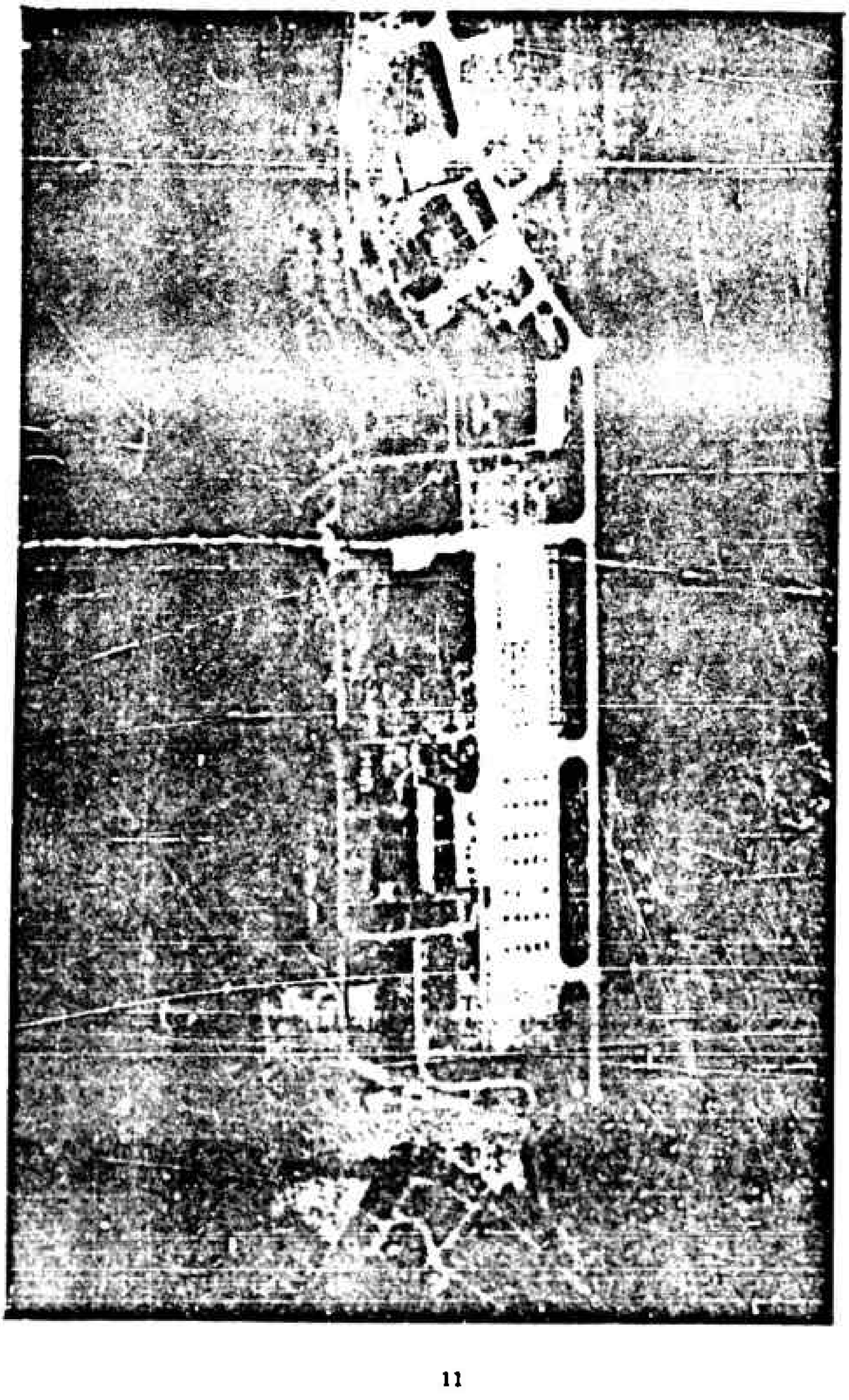
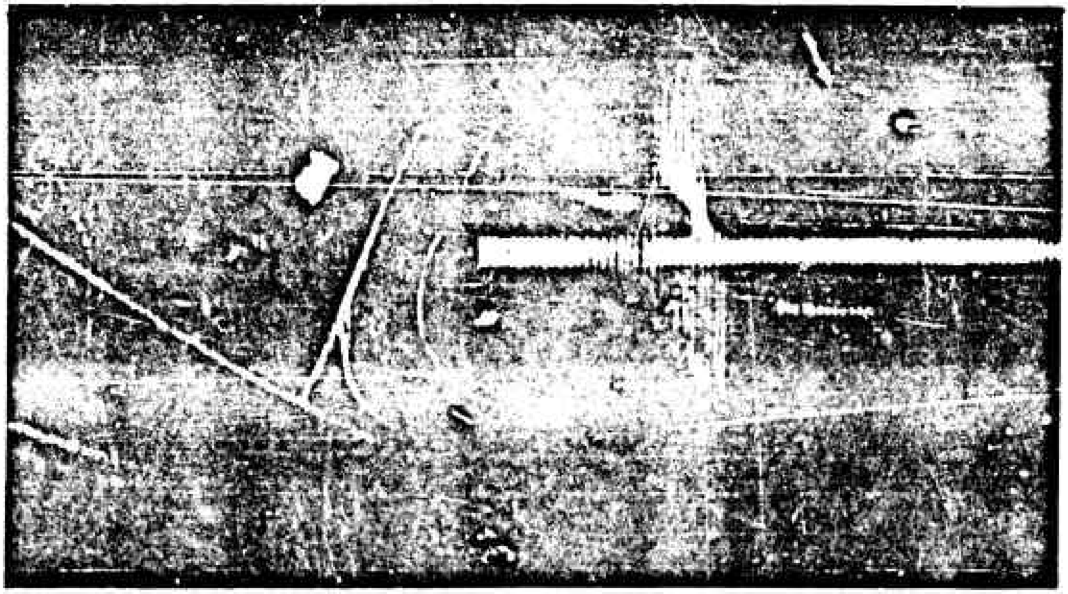


Figure 5. Night IR Photograph



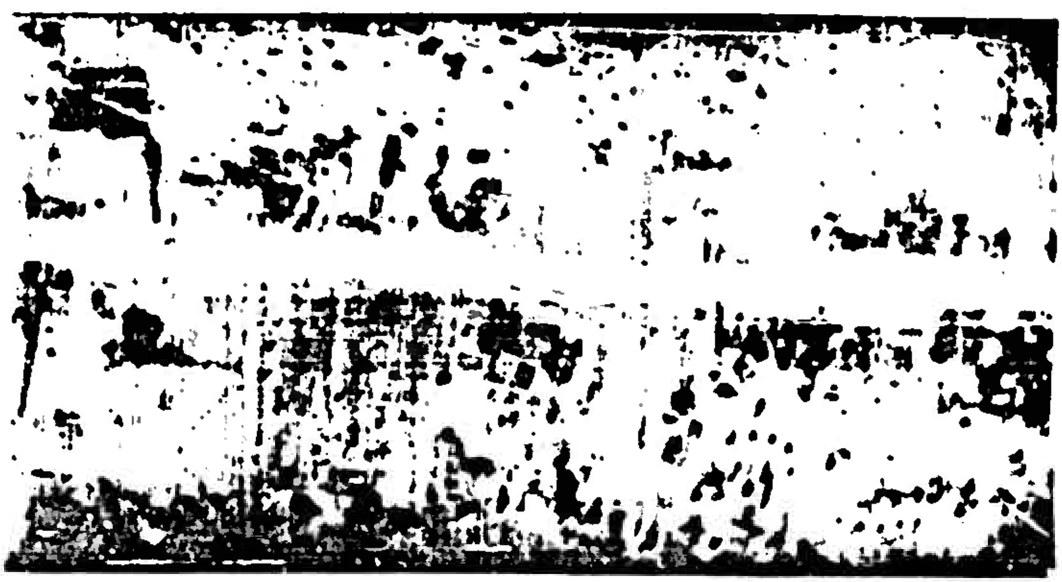


Figure 6. D-5 Photographs

grew progressively worse during the early stages of the deployment until it was decided during the middle of September to change the tube. While attempting to change the tube, it was discovered that the wiring diagrams were not complete enough to complete the change. Based on this and the recommendation of the contractor, the system was sent back to Dalmo-Victor on 27 September 1967 for rework. The system was hand carried back to Udorn by a Dalmo-Victor technical representative on 13 November 1967, was reinstalled and ready for flight testing on 15 November 1967.

It is difficult to determine whether the data collected on the one operational flight has any validity because of the defect in the tube. However, it was determined by the sensor operator that target detection would have been doubtful. Lighting conditions in the area were good - 3/4 moon, excellent visibility, a high thin overcast having little adverse effect. Trees and shadows along Route 110 created contrast patterns much the same as trucks. There seemed to be insufficient definition ability inherent in the LLLTV to distinguish a truck from a tree or shadow on the road. As with the FLIR, the low altitude of operation causes a low grazing angle and complicates the operator's job of picking out trucks from among the trees and foliage. It is apparent that the sensor must be directly aligned on the road to have any opportunity of target detection at lower altitudes.

The LLLTV was evaluated during the last two weeks of flying operations for nine flights in the Udorn local area. It was test flown from altitudes of 500 to 10,000 feet. It was determined that it could be used as a navigation aid at light levels down to 1/4 moon. Below 1/4 moon, useful navigational information is extremely limited. The effective altitude for use as a navigation aid depends on the precision desired and on the light level. At light levels of 1/2 moon or greater, gross navigation (i.e. well-defined roads and rivers, etc.) can be accomplished even up to 10,000 feet. Naturally, the lower the altitude the more detail that can be seen and the better the contrast and resolution of the viewed scene. However, flying too low (below 1,000 ft) decreases effectiveness because of increased relative motion of aircraft to the ground. At light levels between 1/4 and 1/2 moon, the LLLTV is effective as a navigation aid with optimum operating altitude between 1,000 and 2,000 feet. It should be pointed out, however, that the LLLTV has no capability for depth perception and its use at low level in mountainous terrain would be limited. A further disadvantage is that, with ten degrees depression angle, the horizon degrades contrast of the viewed scene by making the picture too bright.

During this time period, tests were also conducted to determine the feasibility of the LLLTV as a target detection device, although it was realized that this wide angle system was not designed as such. Tests conducted bore out the fact that it was not able to detect vehicles. Repeated runs were made over a 3/4-ton pickup truck on a single lane dirt road. The sensor operator was unable to discern the unlighted truck from tree shadows along the road. Another lens assembly of the narrow angle or zoom variety is required if target detection is desired.

For the first few flights after the new tube was installed, tube sensitivity was very good, and point light sources stood out vividly in the display with a minimum of blossoming. One problem encountered, however was that at a distance, fires and lights from other sources looked alike. The LLTV was damaged during a daylight flight three flights before the end of the flight testing program. It was obviously caused by reflection from the sun, but the reason is unknown, as the iris control was on MANUAL and turned all the way down. A permanent streak was etched diagonally through the center of the tube. The last flight on which the LLLTV was tested, which was after the damaging of the tube, point light sources caused an exceptional amount of blooming. In addition, a blurred section appeared on the tube which looked quite similar to the defect which marred the previous tube. It is likely that the reflected light caused this damage.

During the evaluation of the LLLTV, the sensor operators favored the Sony monitors to those furnished by Dalmo-Victor. The contrast appeared much better on the Sony monitors, although the Dalmo-Victor monitor seemed to have better resolution.

All test flights for the LLLTV were conducted concurrently with the bow operator using his naked eye or the starlight scope. Periodically, the sensor operator a[illegible]e bow operator exchanged positions; and at various times, other individuals compared [illegible] eyes, the starlight scope, and the LLLTV. It was the consensus of opinion that a bow [illegible]ver who is night adapted can see as much, if not more, with his naked eye or the 40-degree FOV starlight scope than with the LLLTV.

4. ACTIVE MAGNETIC DETECTION SYSTEM (AMDS)

This system is a prototype model which was installed primarily to gather test data, determine system weaknesses and capabilities, and provide guidance for future development. Any operational value would be a side benefit.

During the early part of the deployment, the system was used regularly against targets of opportunity in conjunction with the other on-board sensors. Targets were detected only sporadically, and numerous false target responses were recorded. It became apparent that considerable calibration and adjustment of filter elements would be required to optimize the system effectiveness. In addition, repeated tests against controlled ground targets would have to be flown in order to gather target signature characteristics. It was then decided to defer further testing of this system and direct the full effort toward evaluation of the primary equipment.

A final effort to obtain some meaningful results from the AMDS was launched during the last two weeks of the deployment. Two company technical representatives arrived and a series of test flights were flown. A number of field modifications were made in attempts to attenuate unwanted signals, compensate for local terrain effects, and optimize gain settings. It is felt that considerable progress was made which should be reflected in follow-on designs.

It should be pointed out that this system will not by itself identify a target. Its value lies in providing an alert that a target has been detected and subsequent identification must be accomplished by other means. This properly fits in with the multi-sensor concept under which this project was developed.

5. NAVIGATION SYSTEMS

a. LORAN C - Inertial Navigation System

The LORAN C - Inertial Navigation System was never successfully integrated and, therefore, no evaluation of its performance is possible. The reason for the failure to integrate the system can be narrowed down to two primary areas:

(1) The LN-15 Inertial System could not be brought to function properly until the very end of the deployment.

(2) The interface problem of integrating the ARN-78 and the LN-15 with the Verdan computer was never completely solved because of difficulties with the computer program accepting data from these two systems concurrently.

The ARN-78 functioned satisfactorily in the free LORAN mode for the most of the program duration. During the last three weeks of the deployment, a few modules malfunctioned; but, overall, the ARN-78 was a reliable item of equipment. With the assistance of extra technical representatives from Litton, the LN-15 functioned satisfactorily for certain brief periods of time. An all-out attempt was made during the latter stages of the deployment to integrate the system. Litton provided two extra technical representatives, and LTV Electrosystems provided one. Four days before the termination of flight testing program, the LN-15 was flown successfully in the free inertial mode of operation. Unfortunately, however, a module on the ARN-78 had failed; so a final attempt to integrate the system could not be accomplished.

b. APN-153 Doppler Radar Set

The APN-153 Doppler Radar Set functioned well throughout the program, and it was regularly used in conjunction with the Verdan computer in the DR mode and also with the ASN-25 Dead Reckoning Computer, which functioned normally throughout. As stated in previous Activity Reports, the only successful tactical navigation device was the Doppler Navigation System combined with the ASN-25 using heading inputs either from the inertial System, when it was able to furnish reliable heading information, or from the aircraft compass system. This system, although reliable, is not suitable for obtaining precise navigational data.

c. ASN-67 Roller Map Dead Reckoning Display

The ASN-67 Roller Map Dead Reckoning Display never functioned properly in the aircraft due essentially to problems in its computer. It was returned to the Weapon Systems Test Center, Patuxent River, Maryland twice for rework, but still was inoperable. It was unfortunate that this system was not evaluated because it was felt that a roller map type of display, with accurate inputs of heading, drift, and ground speed could be an excellent method of navigation for a multisensor aircraft. It would adequately solve the two problems confronting the pilot and navigator:

(1) A means to obtain a precise geographical fix of any target that arises.

(2) A method to follow a road, river, etc.

Equipping the point mechanism of the roller map which traces the aircraft's path with a marking material of some sort would provide a useful post flight analysis tool.

The question arises, is it absolutely necessary to have such a precise navigation system as the proposed accuracies of the LORAN-inertial System would have provided? For a real-time sensor aircraft with a self-contained strike capability, or even a sensor aircraft working in conjunction with a strike aircraft (Hunter/Killer) a highly accurate system hardly seems necessary. Strike and forward air control aircraft appear to be having little navigation difficulty in locating Communist infiltration routes in Southeast Asia today. Of course, the more accurate the navigation system, the easier the job becomes for the aircrew. For a multi-sensor aircraft, whose function it is to reconnoiter an area over extended durations of flight, finding such things as truck parks, troop concentrations, storage areas, etc., and then passing the information on for subsequent analysis and/or strike, an accurate navigation system is necessary and desirable. However, the trade-offs in equipment complexity, cost, and maintainability under field conditions should be taken into account.

6. TERRAIN FOLLOWING RADAR (TFR)

The terrain following radar functioned satisfactorily throughout the testing period. The APQ-110 has certain limitations, however, which seriously affect its value for low altitude operations in mountainous terrain. The system is not roll stabilized, and contains only one channel capability (the crew may select either terrain avoidance or terrain following, but not both simultaneously). So that a crew may fly a constant altitude in mountainous terrain at night with any degree of confidence, a concurrent display of the command bar and a view of the forward terrain in the area is highly desirable.

SECTION V

CONCLUSIONS

1. The operational evaluation of Project MUDDY HILL revealed that the system was incapable of performing night reconnaissance effectively. The major reasons were excessive equipment malfunctions and marginal performance due to maintainability demands beyond the capabilities of the assigned technicians. Related causes were a lack of sufficient spares and an inadequate checkout before deployment. Furthermore, the operational missions revealed limitations in the system equipments which, even with near optimum performance, made it doubtful that the objectives could have been successfully accomplished.

2. The FLIR III is not suitable as a target detection device in Laos-type topography. Roads are extremely narrow, heavily masked by trees, and lacking in adequate thermal contrast. In this environment, the FLIR detection range is insufficient to permit the sensor operator to detect a target, identify it, and react as appropriate.

3. The DLIR system provides satisfactory IR imagery, but foliage cover and camouflage seriously affect its usefulness. In most cases, visually sighted trucks could not be detected on the DLIR film during the post-mission analysis. Note the enemy use of camouflage illustrated in Figure 7.

4. The LLLTV is useful for check point verification 5,000 feet under partially moonlit conditions. With near full moon, the LLLTV offers no advantage over eyeball capability. The LLLTV was not adequate as a target detection device because of the difficulty in differentiating vehicles from tree shadows.

5. The precise navigation system (Integrated LORAN- Inertial - Verdan) never achieved operational status and, therefore, was not evaluated. Individual navigation subsystems operated generally within design accuracy limits.

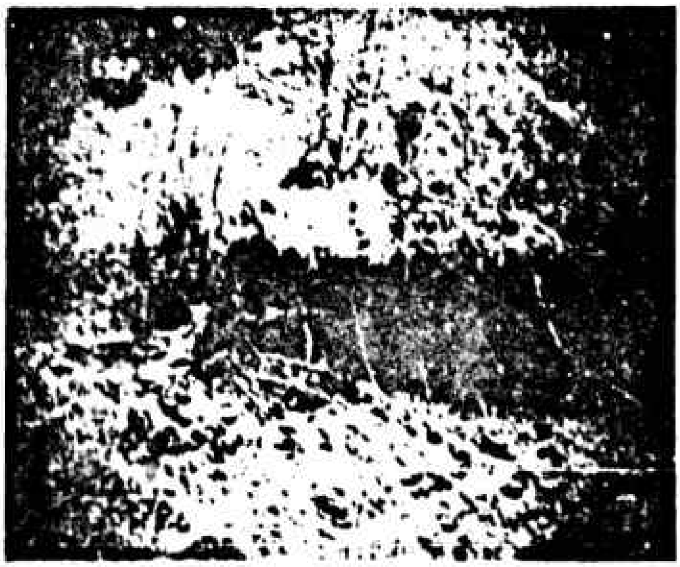
6. The Active Magnetic Detection System (AMDS) operated satisfactorily during the closing weeks of the deployment. The system, by itself, can only indicate the presence of a target, and identification must be obtained by some other means.

7. One of the most critical problems encountered was the difficulty in trying to follow a narrow, winding road at 1,000 feet altitude. Figure 8 is a day photograph of a section of Route 110. A successful technique that was developed to perform this task was the use of a wide FOV starlight scope by the bow observer, who relayed steering commands to the pilot.

8. The project management structure provided little opportunity for the Navy to participate in the early equipment selection, aircraft configuration, and overall planning. Had this been done, it would undoubtedly have provided an additional motivation or incentive to the Navy personnel concerned.

9. In summary, the Muddy Hill system was not effective as a night road reconnaissance system in Laos. This is a conditional conclusion, based on a relatively small sample size because of numerous equipment technical problems and less than optimum system performance. The value of the project lies in the application of the lessons learned and in the elimination of exposed deficiencies in follow-on programs.

MOVING TRUCK



PARKED TRUCK

Figure 7. Enemy Use of Camouflage

Figure 8. Route 110 in Southern Laos (Note narrow winding road and dense foliage)

SECTION VI

RECOMMENDATIONS

1. FLIR

a. Greater detection range is required. Operations at 1,000 feet and 180 knots result in low grazing angles and insufficient reaction time for the sensor operator.

b. An expanded display would enhance target detection and identification capability. This combined with a range increase, would permit higher operating altitudes, wider area coverage, more time for target search, and sufficient reaction time necessary for a self-contained strike system.

c. A "zoom" type display feature would be desirable. This would allow the operator to select a sector of the display and magnify it for target study.

d. Roll stabilization of the scanner platform is considered mandatory in future systems. Also, the scanner should be steerable in azimuth to allow a continuous scan of the winding roads which the aircraft is unable to follow.

e. A cockpit display monitor is of little value to the pilot and should not be installed. If an automatic bombing system is utilized, steering commands to the pilot should be displayed by some means other than on a FLIR scope.

f. The possibility of developing some sort of moving target indicator for use with a FLIR system should be explored. Enemy vehicles move slowly and are often covered with vegetation for camouflage - thus exhibiting little thermal contrast with surrounding objects.

2. DLIR

a. DLIR systems should be configured to permit inflight monitoring of signal levels and adjustment of gain controls to compensate for varying weather and terrain conditions. In the present design, the quality of the film is not assessable until the film is removed and processed.

b. Electromagnetic interference is a major problem and should be given careful consideration in any future design. Even air traffic control ground radars produced noise signals on the DLIR film.

c. A real-time display would be desirable.

d. Calibration and adjustment controls and equipment should be available and designed for use in field operations. In this project, out-of-focus optics, poor contrast, lack of definition, and improper printing densities were common causes of inferior film quality. Excessive manhours were expended in trying to correct these deficiencies. Figure 9 shows two examples of night IR photography obtained with the DLIR.

3. LLLTV

a. If target detection is desired, a narrow angle lens or a "zoom" capability is necessary.

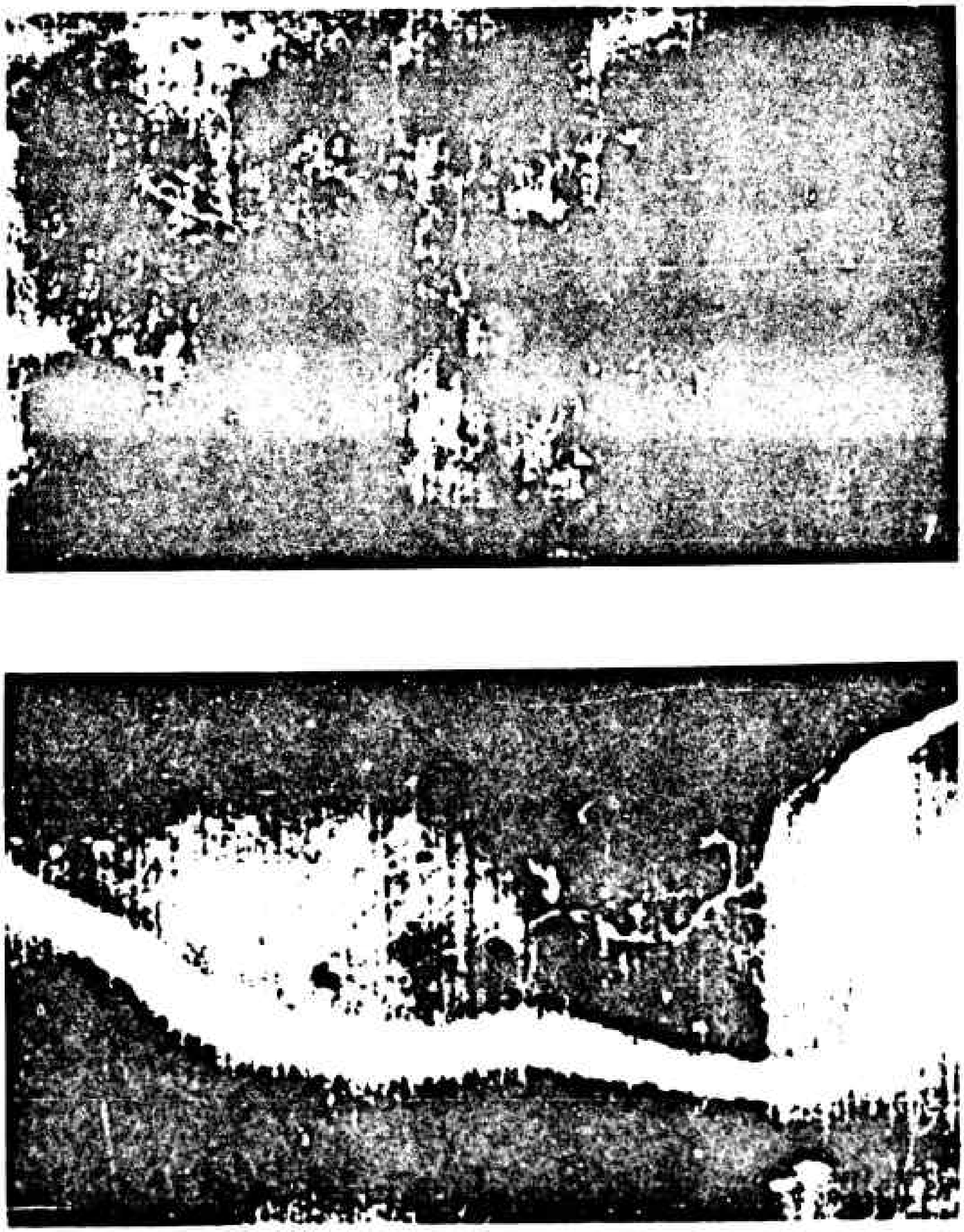


Figure 9. IR Photography of Route 110

b. Safety features should be incorporated to insure that bright reflections will not damage the tube.

c. System electronics should be improved to allow viewing in light levels less than 1/4 moon.

d. A TV display should not be installed in the pilot's position. Besides losing his night vision adaptation, the pilot cannot afford to concentrate on the display at the expense of his other vital functional requirements.

4. AMDS

a. The limited evaluation conducted on this system demonstrates that the device exhibits sufficient potential to warrant continued development. An improved version of this system is presently undergoing test at the company's test site near Austin, Texas, and experience gained from Project Muddy Hill should contribute toward the success of that effort.

b. Looking back, it appears that the system should not have been included in this project because it was highly developmental and could not be given the attention it required.

5. NAV SYSTEM

A highly sophisticated navigation system, because of cost and complexity, is not required for a real-time reconnaissance system. A suitable device is a roller map with appropriate equipment to provide heading, drift, and ground speed input.

6. GENERAL

a. New systems, especially one-of-a-kind, should not be deployed until they can demonstrate reasonable reliability. This is a lesson known but seldom heeded. Of 62 flights flown in SEA on this project, 22 were with the FLIR inoperative, 34 with the LLLTV inoperative, and 23 with one or the other of the D-5s inoperative. In addition, most flights were flown with these equipments, although operational, only marginal in performance. Even more disturbing, on no more than half a dozen flights were all three of these sensor systems capable of operating simultaneously.

b. If practicable, individual sensors should be separately tested before being integrated into a multisensor system. This would isolate equipment problems from installation problems, reduce total system down time and allow concurrent testing which would effectively speed up test schedules.

c. Simulated test sites should be comparable to the real environment. The FLIR III achieved moderate success in detecting targets on certain roads believed to be representative of those in Laos. But the actual roads being used by the enemy in Laos are hardly more than trails, are heavily masked by trees, and present a challenge to the sensor operator rarely encountered on test missions. This factor supports the logic of conducting evaluation programs in the actual environment.

d. A higher operating altitude should be considered for this type of mission. The Muddy Hill operating altitude of 1,000 feet did not appear to furnish the optimum system capability. This altitude was probably arbitrarily chosen in deference to sensor detection limitations without regard to other important factors. Increasing the operating altitude would provide a higher grazing angle for added reaction time, a larger area coverage for target search, easier road following, safer terrain clearance in mountainous country, and reduced vulnerability to ground fire, with very little sacrifice of sensor performance.

e. A self-contained strike capability should be provided with this type of reconnaissance system. Target marking (unless covert) and command vectoring of strike aircraft are ineffective tactics against mobile targets. This method is presently used in night operations with flare ships and FAC's and the ratio of destroyed to detected trucks is pitifully low.

APPENDIX I

APPENDIX I

SYSTEM DESCRIPTIONS

A sketch of the aircraft showing the location of the major equipments is contained in Figure 10.

1. FLIR

a. The Forward Looking Infrared System was manufactured by Texas Instruments, Inc., and is company-designated as FLIR III. It is a multichannel infrared scanning device with real-time displays intended for use in night tactical reconnaissance as a target detector and for checkpoint verification as an aid to navigation. The system is capable of detecting IR radiation in the spectral region of 2 to 14 microns. It includes six Mercury doped Germanium (Ge:Hg) detectors which have optimum sensitivity in the 8 to 14 micron region, and three Indium Antimonide (InSb) detectors with optimum sensitivity in the 3 to 5 micron region. The Ge:Hg detectors provide general coverage of all objects displaying a temperature differential, while the InSb detectors are useful primarily in the detection of intense sources of IR radiation (hot spots). The design spatial resolution is two milliradians and the thermal resolution is 1 1/2°C for the InSb and 0.7°C for the Ge:Hg.

b. The system consists of a scanner unit, a heat exchanger, two power supplies, an electronics unit, an inverter, two control units, and three identical display monitors. Total system weight is 355 lb. System operation requires an electrical input of 28 volts DC and 115 volts, 3-phase, 400 Hz AC.

c. The scanner unit contains mechanical scanning and optical assemblies which produce a 20 by 40-degree field of view. The scanner can be manually controlled from 0 to -90° elevation. Azimuth scan is achieved by rotation of a rectangular four-sided mirror and elevation scan is obtained by rotating an array of four circular mirrors. Rotation speeds are 15,000 RPM for the azimuth mirror and 211 RPM for the elevation mirror assembly. Nine low-level, low-noise, welded module preamplifiers are installed in the scanner to amplify the detector video outputs.

d. The heat exchanger and cryogenerator provide an operating environment for the detectors of less than 27° Kelvin achieved after approximately 16 minutes of operation. The cryogenerator is manufactured by Norelco, and operates on the Sterling-cycle principle using helium as a refrigerant. The heat exchanger circulates a coolant oil to accomplish its heat transfer functions. This type of cryogenic system is used in several other military IR systems, such as the AN/AAS-18, AN/AAS-10, and the AN/AAS-21. The detector array and cryogenerator cold-finger assembly are contained in an evacuated chamber which serves to insulate their elements from the ambient air. The vacuum is maintained by a small Vacion pump electrically operated from a 3000-volt DC power supply. The power supply input voltage is obtained from a 12-volt DC nickel-cadmium battery which is recharged automatically from the aircraft 28-volt DC bus.

e. Two power supplies provide the low voltages necessary for the system electronics circuitry. They provide required DC power and servo power to control and drive the scanner to the selected depression angle. The electronics unit contains the

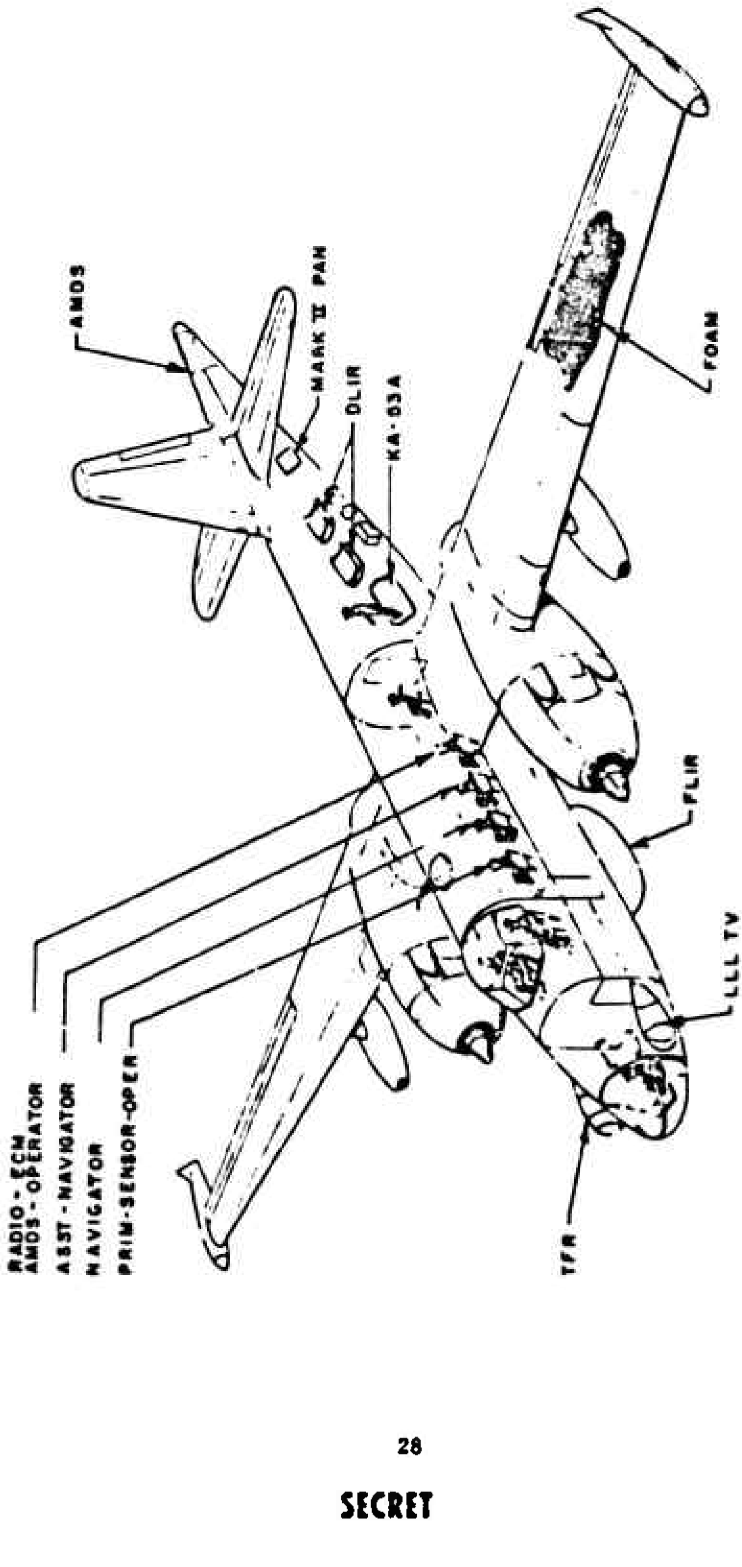


Figure 10. Major Equipments

horizontal and vertical sweep generating circuitry and the video processing circuitry. A modified 400 Hz inverter is used to convert a 28-volt DC into a 3-phase, 500 Hz AC voltage to drive the azimuth scan mirror assembly.

f. Control units are located at the main sensor operator's station and the bow observer's station. Either position can select the type of detector video signal to be displayed on the monitor, the amount or percentage of this signal, the threshold level of the hot spot circuitry, and the scanner depression angle.

g. Display monitors are installed at the bow observer, pilot, and main sensor operator stations. The monitors contain Matricon display tubes, with P1 (green) phosphor coating and a viewable screen measuring 3.5 inches in height and six inches in width.

2. DLIR

a. The Downward Looking Infrared Surveillance System is a multichannel infrared recording device designated SD-5 by the manufacturer, Texas Instruments, Inc. Infrared radiation is detected in the 2- to 14-micron spectral region with multichannel operation achieved by using ten matched Mercury doped Germanium (Ge:Hg) detectors. An array of five detectors provide coverage in the 2- to 14-micron region while another five-detector array is spectrally filtered to cover the 3- to 5-micron region for hot spot detection. The system can record video signals obtained only from one detector array at a time.

b. The system is composed of two identical subsystems that can operate independently. Each subsystem consists of a scanner/recorder assembly, a power supply, a remote electronics box, a control unit, and a heat exchanger. Total weight of the system is 545 lb. The spatial resolution is 1/2 milliradian and the thermal resolution is 0.5°C.

c. The scanner/recorder units are mounted on the floor of the aft fuselage, the forward scanner tilted 12 degrees past vertical, looking back, and the aft scanner tilted 12 degrees to view forward. This provides a 24-degree overlap of the mapped terrain and produces stereo IR imagery for post mission analysis. The scanners are roll stabilized to ±10 degrees.

d. The thermal image of the scanned terrain is continuously recorded on a roll of TRI-X 5-inch reconnaissance film. Automatic and manual V/H (velocity to height ratio) are provided with a range of 0.01 to 0.5. At the maximum V/H of 0.5, a roll of 350 feet of film provides two hours of recording time on each scanner unit. Electrical inputs of 28 volts DC and 115, 3-phase, 400 Hz AC are required for system operation.

e. A rectangular, four-sided mirror is rotated about an axis parallel to the flight path and produces a conventional line scanning pattern, ±65 degrees laterally below the aircraft. The mirror rotates at a constant 3,000 RPM. The signals obtained from the detector array are modulated, processed, and transmitted to the film to provide a panoramic printout four inches wide.

f. A separate cryogenic refrigeration system is provided for each scanner. A Norelco closed-cycle cryogenerator, operating on the Stirling-cycle principle, is used in conjunction with a heat exchanger. Helium is used as the refrigerant in the cryogenerator and a coolant oil accomplishes the heat transfer in the heat exchanger. A similar cryogenic system is used in the FLIR III. Cool-down to less than 27° Kelvin is achieved in approximately 25 minutes. The detectors and cold-finger assembly are contained in an evacuated chamber that is maintained by a small Vacion pump powered from a 12-volt DC nickel-cadmium battery.

g. The control units for the system are located at the main sensor operator's station. Fault indications and a V/H limit lamp are provided.

3. LLLTV

a. The Low Light Level Television System is a wide angle television system manufactured by the Dalmo-Victor Co. It consists of a camera mounted on a two axis steerable platform, a camera electronics box, a servo electronics box, display monitors, and interconnecting cables. Electrical inputs of 28 volts DC and 115 volts, 3-phase, 400 hz AC are required for system operation. System weight is approximately 125 lb.

b. The camera consists of an Image Intensifier - SEC Vidicon camera head. The image intensifier contains a Machlett extended S-20 type photo cathode surface. The photo cathode diameter of the intensifier is 25 millimeters with an f/1.0 lens providing a 30- by 40-degree field of view. The camera is contained in a cheek pod mounted on the left side of the aircraft forward of and below the pilot's position. The camera head and lens are mounted on a platform which is steerable in azimuth and elevation. Limits of azimuth travel for the platform are 25 degrees to either side of centerline and limits of elevation are from 10 degrees above to 80 degrees below the aircraft armament datum line. Basically, the concept of operation is that light energy from a viewed scene is transmitted and amplified by the image intensifier, and is further amplified and then coupled to the display monitor by the SEC-Vidicon tube.

c. Originally, there were two 6-inch display monitors used to portray the scene being viewed by the camera. One monitor was at the sensor operator's station and one in the cockpit. However, due to constant failures of high voltage power supplies and printed circuit electronics boards, it was decided to replace the display monitors with commercially available Sony television sets. One 9-inch Sony replaced the monitor at the sensor operator's station, and another was installed in the Plexiglas bow station. A 5-inch Sony replaced the display monitor in the cockpit. The original monitors contained a cross reticle displayed on the screen to indicate the location of the camera azimuth and elevation axis with respect to the aircraft longitudinal axis. However, after the Sonys replaced the display monitors, this feature was eliminated. It was not felt that this loss would detract from system effectiveness.

d. The sensor operator's control console contains indicators and controls necessary for controlling the camera platform. The platform can be steered by a "joystick" type hand control at the operator's position. Meter readouts furnish an indication of camera position with respect to the aircraft's horizontal and vertical axis. A hand control is also located at the pilot's position which includes an override feature. A further control on the operator's console is an iris selector switch for controlling the camera lens iris either manually or automatically.

e. The contractor specifications stipulated that the LLLTV should provide a target acquisition device as well as a navigation aid at light levels ? 10^{-4} foot candles. This light level can be compared to a starlit night with clear skies and no moon. Under the Muddy Hill concept of operations, the LLLTV was intended primarily as a navigation device. Ideally, the system was designed to out-perform the human eye by at least one order of magnitude. The manufacturer's specifications were demonstrated by means of an Optoliner check on 21 December 1966. The Optoliner was connected directly to the input stage of the image intensifier which effectively eliminated the lens and the filter from the test. Under the condition, the system met the contractor's resolution specifications. However, it was realized that the lens and filter would somewhat degrade the resolution of the viewed presentation at the monitor.

4. AMDS

a. The AMDS is an airborne electronic device capable of detecting targets that are either electrically conductive or magnetically permeable. The system is termed active because it generates a strong magnetic field which is directed in a forward plane about 45 degrees below the aircraft flight path. When this field impinges on a target, a small magnetic field is induced which is coherently detected and electronically processed to provide a visual and an aural indication of the target. The system consists of ten component units weighing a total of 516 lb; it is manufactured by the Electro-Mechanics Co. (EMCO) of Austin, Texas.

b. The major unit of the system is the coil/sensor assembly, which is mounted in the specially reinforced nonmetallic tail cone. Figure 11 is a sketch of the physical layout of this unit. A 200-turn field generating coil and a ferrite sensor are mounted on either end of a 12-foot, 30-inch diameter fiber glass cylinder. The coil is mounted on the forward end, and it and the sensor are rotatable to achieve a mechanical alignment. A high current is produced in the coil and generates a magnetic field along the coil axis. The coil and sensor are canted so that the direction of the maximum generated field intensity and the direction of maximum sensor sensitivity are coincident in the forward 45 degree plane.

c. A receiver unit contains electronic circuitry to process the signal received from the ferrite sensor. The receiver output, which is an analog signal representative of the target, is sent to the detector for further processing. Here the phase and amplitude of the signal are determined, and the final output is fed to the target indicators.

d. Any target detected by the system is indicated in the following three ways:

(1) A remote meter unit provides meter deflections corresponding to the target signal. The null indication is at the center of the meter face, and amplitude and polarity of the signal are indicated by the meter needle fluctuations.

(2) An audio signal is generated through a voltage controlled oscillator which produces an audio tone of varying frequency representative of the detected target. A standard headset may be used to monitor the tone signal.

(3) A strip chart recorder, which furnishes up to eight hours of recording time, graphically displays the received signal. Amplitude and polarity are recorded and provide data for post-mission analysis.

5. NAV SYSTEMS

The Muddy Hill aircraft had three navigation systems installed:

(1) LORAN C - Inertial Integrated Navigation System, which was designed to be the primary system.

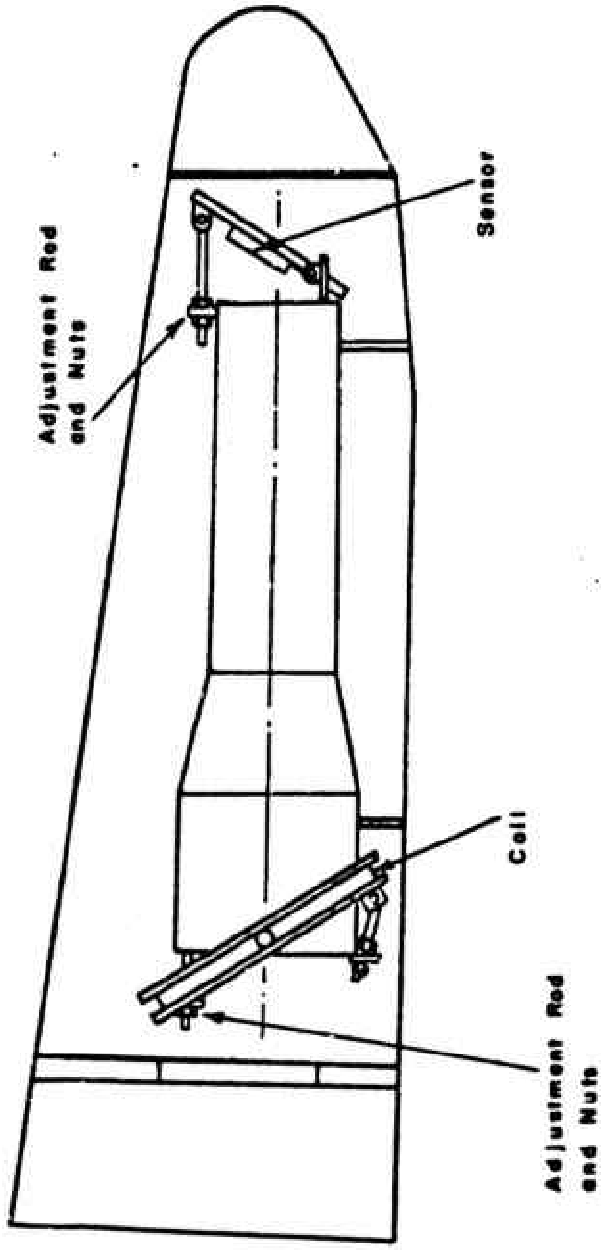


Figure 11. AMDS Coil/Sensor Assembly Physical Layout

(2) Doppler Navigation System - a backup system.

(3) AN/ASN-87 Roller Map Dead Reckoning Display Set - another backup system which was added just prior to deployment.

a. LORAN C - Inertial Integrated

The LORAN C - Inertial Integrated Navigation system contained the following components:

AN/ARN-78 LORAN C (Modified) Receiver Set

LN-15 Digital Inertial Navigation System

Versatile Digital Analyzer (Verdan) Computer

AN/APN-153(V) Doppler Radar Set

G-2/MF-1 Aircraft Compass System

The AN/ARN-78 LORAN C (Modified) Receiver Set is a fully automatic, digital microcircuit signal detection and track device. It receives, measures, and indicates the time differences from LORAN C stations. Although the set was originally built as an AN/ARN-78 LORAN C Receiver Set, the receiver/power supply portion was modified in order to provide an output of digital interface signals to the Verdan computer. In effect, this modification made the set quite similar to an AN/ARN-85. When operated by itself not in conjunction with the Verdan, the AN/ARN-78 has the capability of producing a continuous readout in LORAN time difference on its indicator. Time differences can be received from two LORAN C chains simultaneously, and these can be plotted on a LORAN chart to provide a geographical position. The design accuracy of the LORAN C system is about 1/10 of a nautical mile.

The LN-15 Digital Inertial Navigation System is a fully automatic, self-contained, all latitude and longitude navigation system. Initial position coordinates and the desired heading are manually inserted into the system before take-off. The gyro stabilized platform is aligned parallel to the earth and to a known azimuth reference, and then, by means of accelerometers, the LN-15 measures accelerat[illegible] along the axis of alignment. These accelerations are converted to X, Y, and [illegible] velocities by the LN-15 computer and further processed to produce latitude [illegible] longitude coordinates, true heading, altitude and pitch and roll attitude. [illegible] design accuracy of this inertial system is 1/2 nautical mile per hour CEP.

The Versatile Digital Analyzer (Verdan) Computer contains universal, general purpose, digital difference analyzer, shaft voltage, and memory sections. It makes calculations for four modes of operation: LORAN-INERTIAL, LORAN, INERTIAL, and DEAD RECKONING.

(1) In the LORAN-INERTIAL mode of operation, the Verdan Computer takes information from both systems, computes a position, and displays it on the System Control Board in Latitude/Longitude coordinates. It accepts initial position, X, Y, and Z velocities, and heading reference from the LN-15 and accepts continuous position updating and dampening information for the LN-15 from the AN/ARN-78. Simultaneously, inertial velocity and rate aiding signals are fed to the LORAN to provide more accurate tracking of the receiving signals.

Theoretically, the degree of accuracy expected from this system is a 350-foot CEP at any time over any duration of flight.

(2) In the LORAN mode, the Verdan uses only LORAN time differences to compute a position. The Doppler Radar provides a velocity reference to the Verdan in this mode.

(3) In the INERTIAL mode, the LN-15 provides X, Y, and Z velocities and heading inputs to the Verdan computer which computes a position.

(4) In the DEAD RECKONING mode, the AN/APN-153(V) Doppler Set provides ground speed and drift, while the G-2/MF-1 compass system or the LN-15 provides heading to the Verdan, which computes a position.

In each case, the present position is displayed on the Navigator Control Panel as Latitude/Longitude coordinates. When in the LORAN-INERTIAL mode, a malfunction of either the LORAN or inertial systems causes the Verdan computer to automatically switch to the next lower available mode of operation. If both LORAN and inertial systems malfunction, the Verdan switches to the DEAD RECKONING mode of operation.

The System Control Panel, located at the Navigator's Station, is used to provide control of the Verdan computer operations regarding navigation computations. The panel contains indicators to inform the operator of the status of the navigation equipment, i.e., Go/No Go indications for the Verdan, Doppler, LN-15 and alarm indications when the LORAN information is unreliable. This panel also contains controls for position display on the Navigation Control Panel. The Navigation Control Panel contains a present position readout as well as Position Entry and Destination Select switches, which allow for insertion of present position and display of range and course to pre-selected destination.

b. Doppler Navigation System

The Doppler Navigation System operates independently of the primary navigation system and consists of two components: The Doppler Radar Set AN/APN-153(V) and the Navigation Track Computer Set, AN/ASN-25, both manufactured by the GPL Division of General Precision, Inc. The system performance criteria specifies that the maximum inflight error must be less than 2% of distance traveled. In addition to functioning as a navigation system, the Doppler Navigation System provides inputs to the Terrain Following Radar (TFR) and the Verdan computer.

The Doppler Radar Set measures ground speed and drift angle continuously and displays them on its control indicator. The ground speed and drift angle, supplemented by heading information from the MF-1 compass or the LN-15 Inertial Navigation System, provide electrical inputs to the Navigation Track Computer.

The Navigation Track Computer Set or Dead Reckoning Computer, AN/ASN-25, consists of a computer amplifier, a computer control, and a short-range indicator. The set is a completely transistorized, dual-channel track navigation computer. Desired track and distance for individual segments of flight are set into the computer manually. With ground speed and track-made-good signals from the Doppler Radar Set, the computer will continuously display aircraft position in relation to the desired track, i.e. nautical miles to go and nautical miles right or left of desired track. When one segment of flight is complete, the computer automatically begins its display of the next segment. A short-range indicator which allows greater precision (.05 nm) in setting and reading the nautical miles to go is also included on the display panel.

c. AN/ASN-67

The AN/ASN-67, Roller Map Dead Reckoning Display portrays aircraft geographical position on a strip of standard aeronautical chart. The set is furnished ground speed and drift angle from the Doppler and heading information from either the G-2/MF-1 Compass or the LN-15 Inertial System. The track of the aircraft is shown by continuous vertical movement of the chart strip. The system has a cursor with a diamond point which indicates the present position of the aircraft as well as its displacement right or left of desired track. Chart strips can be spliced together up to a maximum length of ten feet when using charts with 0.003 thickness. The chart strips are installed on a cartridge which can be removed in flight for replacement with different cartridges. The system is capable of using four specific sizes of map scales.

6. TFR

a. The Terrain Following Radar (TFR) is a special purpose airborne radar manufactured by Texas Instruments, Inc. It is basically an APQ-110 (utilized in the F-111) but modified for single channel operation and adapted specifically for use in the Muddy Hill aircraft. The antenna is mounted in a cheek pod on the right side of the forward fuselage. Two identical indicators are included, one in the cockpit and one at the navigator's station. Primary controls are located in the cockpit although the navigator can exercise selected control, especially in the ground mapping mode.

b. The radar set is pulse-modulated at a selectable pre-set frequency in the Ku-band over a frequency range of 500 MHz. PRF is 4025 pulses per second with a peak power output of 30 kilowatts.

c. There are three modes of operation, as follows:

(1) Terrain Following. In this mode, the pilot is provided with optimum elevation commands to fly the aircraft at selectable clearance altitudes from 200 to 1,000 feet. These commands are presented in the form of a "command bar" on the pilot's ARU-11A All Altitude Indicator. The TFR indicator displays an E^2 scope with a ten-mile range. This display shows the template line, and any target which protrudes through this line will generate a climb command. If a terrain feature appears in the flight path which cannot be cleared using normal rated power, an audible warning is given to the pilot. A fail warning light is also installed on the pilot's instrument panel.

(2) Terrain Avoidance. Ranges of 5, 10, or 15 nautical miles are selectable in this mode. The scope displays a ± 30-degree depressed center PPI presentation of the terrain in or above the horizontal plane containing the aircraft. The presentation is drift stabilized, enabling the pilot to make lateral maneuvers to keep his course free of terrain features.

(3) Ground Map. The navigator's cursor control contains all the controls necessary to locate a target while operating in this mode. A tilt control aims

the ± 30-degree PPI-type radar pencil beam at targets of interest. Ranges of 5, 10, and 15 nautical miles are selectable.

7. ABS

a. The Automatic Bombing System (ABS) was designed to provide a low altitude automatic capability for the delivery of marking devices and stores. The system is composed of the FLIR III, a portion of the Verdan Computer, and the necessary controls and interface equipment.

b. The FLIR display contains a stationary horizontal elevation cursor which the sensor operator can position over the target by varying the scanner depression angle. Then, by engaging an attack switch on the ABS control unit, the operator can place a movable vertical azimuth cursor over the target. With the attack switch activated, the Verdan accepts inputs of ground speed, radar altitude, FLIR depression angle, drift angle, heading, and aircraft altitude, and performs the bombing computation. The Verdan provides outputs that control the FLIR scanner elevation angle and displaces the azimuth cursor and index marks on the FLIR display monitor. These index marks are displayed to the pilot as fly-to indicators. When the aircraft is turned so that the index marks coincide with the azimuth cursor, the aircraft is on course for stores delivery.

c. The Verdan also computes a time-to-go signal that displaces a horizontal release cursor. This cursor originates at the bottom of the monitor and moves upward until it reaches the stationary elevation cursor, at which time the armament release pulse is automatically initiated. The operator can break off the attack mode at any time by disengaging the attack switch. A manual release pushbutton switch is also provided. The system was not used overseas because the FLIR detection range was insufficient to allow the ABS sequence to be executed.

8. DECS

a. The Defensive Electronic Countermeasures System (DECS) installed in the Project Muddy Hill aircraft provides radar threat warning, radar band identification, and relative bearing of radars in the S -, C- and X- bands. Defensive ECM (jamming) are available in S-band only.

b. The components of the system are: two TRIM 7 main units and controls, a Vector/Sector control, an analyzer, eight TRIM 7 antennas, four S/C-band antennas, four X-band antennas, eight preamplifiers, and an audio switch panel. Total weight of the system components is 155 lb.

c. The TRIM 7 main units protect the aircraft against threat radars operating in the S-band track mode. Using the technique of inverse-modulation deception, the TRIM 7 automatically repeats pulsed signals received from radar threats. Five deception modes are available:

(1) Inverse Modulation Mode (IM). Deception is achieved by amplifying and repeating pulses that occur in the troughs of the signal from the conical scan radar. The conical scan frequency must be detected in order to achieve effective deception.

(2) Swept Automatic Mode (SAM). A signal from a local amplitude modulation generator is used to time the occurrence of the repeated pulses. The frequency

of this selectable signal simulates the spin frequency of the tracking conical scan radar. The simulated scan modulation is automatically swept from about 4 Hz below up to the selected frequency at a 3-second sweep rate.

(3) Variable Amplitude Modulation (VAM). This is identical to the SAM mode except that the frequency of the simulated scan modulation is set and now swept from 4 Hz below the selected frequency.

(4) Inverse Modulation/Swept Automatic Mode (IM/SAM).

(5) Inverse Modulation/Variable Amplitude Modulation (IM/VAM). The IM/SAM and IM/VAM are combination modes in which the timing of deceptive pulses is assumed by the IM function whenever the scan modulation of incoming signals can be detected. When the scan modulation of the threat radar is not detectable, the pre-selected SAM or VAM frequency determines the timing of the RF output signals.

d. The Vector/Sector Control performs the combined function of a direction finding/warning receiver and sector control for the antennas of the TRIM 7 main units. This unit provides visual and aural alert signals when threat radars illuminate the aircraft and instantaneously indicates the relative bearing of radars. Relative bearing and radar band of the threat radar are indicated on a cathode ray tube. If several threat radars illuminate the aircraft simultaneously, the bearing of each is displayed. The length of the strobe provides an indication of the range to the radar, with the strobe length increasing as radar range decreases. The system was operated during all operational missions but no radar threats were detected.

9. AN/AMQ-17

The Aerograph Set, AN/AMQ-17 is an airborne aerological instrument used to present accurate measurements of temperature, pressure, and humidity. It consists of an Indicator-Recorder mounted in the bow station and an externally mounted humidity/temperature probe. The aerograph set provides continuous readout on counters as well as printed data chart of the measurements made for selected time intervals. The set is used primarily for measuring temperature and relative humidity at altitude to provide these variables for analyzing the data obtained from the infrared sensors.

10. DIGITAL DATA SYSTEM

The Digital Data System is a mission information encoding, indicating, and storage system that provides data matrix information for photography and DLIR imagery and provides post-flight printout of aircraft tactical mission data. Time and mission data are supplied to the system from a programmer and the Verdan computer respectively. Visual display of time, to the second, is provided for use of the flight crew. Mission data is simultaneously converted to serial data in binary-coded-decimal form for recording on magnetic tape. Ground data reduction equipment provides a modified octal printout of mission information for each second of time. Conversion of the modified octal data to decimal must be accomplished manually, which is a tedious and inefficient process and permits the processing of only the most essential mission parameters for specific times requiring data correlation. To obtain plain language printouts of mission data, a costly IBM computer would have to have been bought. For this reason, the system was rarely utilized. The information recorded by the Digital Data System is as follows: Time, Latitude, Longitude, True Heading, Ground Speed, Track, Drift Angle, Radar Altitude, Roll, Vertical Velocity, FLIR tilt, LORAN Time Difference "A", LORAN Time Difference "B" and Barometric Pressure.

11. MARK II PANORAMIC CAMERA SYSTEM

This system consists of a lightweight panoramic camera and mount manufactured by Perkin-Elmer, Inc. It takes successive 180-degree exposures by means of a continuously rotating scanning head prism, a 3-inch E. F. L. F/8 fixed objective lens focused at infinity and a mirror which projects sweeping images of a 180-degree field through a focal plane slit. The resolving power of the optical system is 40 lines/mm. The camera uses 70-mm standard base film supplied on 1,000-foot reels. It is strictly for daytime use and was used only during one day familiarization flight over Route 110.

12. KA-53A CAMERA SYSTEM

This is an airborne reconnaissance system manufactured by Chicago Aerial Industries, Inc. It has a 12-inch E. F. L., F/3.5 to F/6.7 fixed objective lens focused at infinity. It uses standard 5-inch by 250-foot long film. It is a high resolution camera which is capable of operating within a wide range of altitudes and ground speeds. Tactical mission data is provided to the system from the Digital Data System and is annotated on the film. The camera is usable in daytime only and was installed in the aircraft for the purpose of substantiating the accuracy of the data provided by the navigation system.

13. EXPLOSION SUPPRESSIVE FOAM

a. The fuel tanks of the aircraft were packed with polyurethane foam to provide explosion protection against ground fire. Seven hundred and five pounds of foam were required, and the quantity of fuel displaced had no significant effect on aircraft range.

b. The foam produced no adverse effect on aircraft operation. Periodic fuel samples were checked for contamination level, and all results were well below allowable limits. The aircraft accumulated approximately 400 hours of flight since installation of the foam in January 1967. No bullet hits were received by the aircraft. It is believed that the operational experience gathered from this pilot project has added significantly to the existing data and raised the confidence level in the use of this material, which is receiving universal interest.

14. STARLIGHT SCOPE

The starlight scope is a small, lightweight passive night image intensifier device consisting of an objective lens, image intensifier tube, eyepiece, power supply, and reticle assembly. This particular device differs from the standard item in that it has a 40-degree field of view and is a one-power scope. The standard starlight scope has a 10.4-degree field of view and has a magnification of four times. The weight of this scope is approximately six lb, and its dimensions are approximately 14 inches x 3 1/2 inches. It is not mounted to any part of the aircraft, and its use on this program was limited to being hand-held by the bow operator. It served very effectively as a road-following aid.

15. TARGET MARKER

a. The target marker carried on board the aircraft was a standard Mk 24 parachute flare, but modified by removing the flare candle and adding a compensating weight. The 10-foot diameter parachute was coated with a chemiluminescent material which glows with a non-heat producing fluorescence when exposed to air. The parachute canister is dispensed from the sonobuoy chute of the aircraft and contains a pyrotechnic timer for deploying the parachute.

b. During tests conducted in forested areas of Laos and Thailand, the parachutes, when dropped, draped over tree canopies and were easily visible at three to five miles from 1,000 feet altitude. The emitted light deteriorates to about 50% in six minutes and becomes non-visible after about 35 minutes.

APPENDIX II

ASD-TR-68-8

MUDDY HILL DLIR EVALUATION

PRELIMINARY REPORT

20 September 1967 to 17 November 1967

2 December 1967

GROUP 3

Downgraded at 12-year intervals; not automatically declassified

This material contains information affecting the national defense of the United States within the meaning of the espionage laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

Prepared by:
Arthur A. Arro
Compass Eagle Team
HRB-Singer, Inc.
RADC/EMIRC

GENERAL

This report discussed an evaluation of the infrared imagery produced by the two D-5 infrared scanners, installed in a tandem configuration in the Muddy Hill aircraft. The imagery reviewed was collected during the period 20 September to 17 November 1967. This evaluation was conducted during the week of 20 to 25 November. A total of 31 flights which produced 55 lengths of film totaling 4300 feet of film were screened for this evaluation.

OBJECTIVE

The primary objective of this analysis was to evaluate the D-5 image quality, and to determine its effect on target detection.

EVALUATION

To perform an analytical evaluation within the limited time available, the film parameters of contrast, density, resolution and malfunctions were selected and graded independently to arrive at a general image quality rating. The grades of poor, fair, good and very good were qualitatively assigned to each of these parameters. Weather conditions, flight profiles, and time-over-target were also noted if it was felt that they influenced the image presentation. Operational USAF RS-10 imagery was used as the basis for quality comparison.

A total of 21 test flights were made during the test period. Most of these were flown in the vicinity of the Udorn Royal Thai Air Force Base, to determine the results of equipment modifications. Sixteen of these flights were made during daylight hours with nearly ideal weather. The remaining nine flights were made at night. Out of a possible 42 film strips (2 per flight), 39 strips were recorded. On three flights, one of the scanners failed to produce any film. Eighteen film strips, representing 43% of the total available, were graded fair to good. Twenty one film strips, representing 50% of the total available, were rated good to very good in general film quality.

During the 10 operational missions flown over Laos 19 film strips were recorded from both systems. Only once did a system indicate a film drive stoppage during the operational phase. Twelve film strips representing 60% of the operational flights received fair to poor ratings. Seven strips representing 35% of the missions were graded good to very good in image presentation. The times over target and area flown definitely led to the poorer quality of the operational flights. It must be noted that the percentages are valid only to a relative degree due to the small statistical sample used.

Both systems were continually plagued by problems and malfunctions during the evaluation period. Electromagnetic interference (EMI) resulting in striations, banding, video sweep loss and noise spikes on the film record was the most prevalent problems encountered. These malfunctions definitely degraded the detectability of vehicular type targets since their subtle returns are degraded into the background noise. This interference can generally be attributed to external sources such as the doppler navigation radar, IFF, and 400-cycle line noise. The aircraft possesses continual transients and generally most other electronic systems were affected to some degree.

Incorrect equipment gain and level settings degraded much of the DLIR imagery. Subtle targets such as sampans and camouflaged vehicles are not detectable without optimum system settings. Level shifts in both contrast and density affected much of the imagery during the early part of the program. This was partly due to the short time constant of the original D-5 scanner and was alleviated after the time constants were adjusted to agree with those of the RS-10. Variation in printing contrast across the scan, commonly termed shading, contributed to a loss of target information. This shading was prevalent during the latter part of the program.

Roll stabilization problems which caused ground objects to appear "jittered" on the imagery reduced the probability of target detection. Both target size and shape were distorted by this malfunction.

Each scanner had unique problems associated with that system. The aft system had roll stabilization and noise problems while the forward system was continually out of focus. This poor focus condition precluded the fine edge definition required to properly identify targets as found in operational areas. The focus problem degraded the effective spatial resolution to 1.35 milliradians in the forward scanner. Rear scanner resolution was determined to be 0.69 milliradian.

These were the most common system problems which were evident during this DLIR film evaluation. As a summary, a list of conclusions and recommendations have been compiled.

CONCLUSIONS

1. The DLIR D-5 systems were incapable of detecting vehicles in an operational environment with any regularity.

2. Image quality and presentation are definite factors in the detection of subtle targets such as camouflaged trucks infiltrating through southern Laos. Combined D-5 image quality over 10 operational and 21 test flights was rated only fair to good in overall presentation.

3. External electromagnetic interference resulting in striations, banding and noise spikes was the major factor in image degradation. Non-focused optics, poor contrast and printing densities also precluded good image quality.

4. Weather, flight profiles and times over target were insignificant factors in determining image quality during the test program.

RECOMMENDATIONS

1. Future systems should have provisions for monitoring and adjusting the signal and printing levels to compensate for varying terrain and weather conditions. An inflight display would be useful for operator control of terrain presentation.

2. Future systems should be isolated from external sources of electromagnetic interference either by physical separation and/or electrical shielding. This systems power requirements should be filtered also to minimize electrical noise.

3. Future systems should have provisions for easy optical focussing and collimators should be used to maintain the critical focus.

4. Future test flights involving infrared systems should be conducted at night to yield realistic results. Test flights to eliminate noise and interference are an exception.

5. Resolution targets should be overflown at the beginning and end of each mission to readily detect any system degradation.

6. Additional systems for spares should be available in future programs.

7. All future systems should be tested and evaluated over CONUS ranges such as Underbrush at Eglin APG prior to operational deployment.

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13. ABSTRACT

Project Muddy Hill was established to evaluate the feasibility of an airborne multi-sensor night reconnaissance system. It was a Navy project, with a modified Lockheed P-2H as the test vehicle and U.S. Navy personnel from Patuxent NAS, Maryland, assigned to manage and carry out the test program. Two Air Force officers participated in the program as an Air Force Liaison team.

The primary sensors contained in the aircraft were a real-time forward looking infrared scanner, a low light level television, and a pair of downward looking infrared recording devices. After equipment installation, some testing was accomplished at Greenville, Texas, and Patuxent River, Maryland, before the project deployed to Southeast Asia for operational testing and evaluation.

The project was located at Udorn RTAFB, Thailand, for four months, and operational missions were flown over enemy occupied areas of Laos. Numerous technical problems associated with the equipment resulted in excessive out-of-commission status and marginal operational capability. It must be concluded that the project was unsuccessful in performing effective reconnaissance in mountainous jungle terrain but its primary value was in revealing deficiencies to be corrected in follow-on programs.

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